I. C. 6419

JANUARY, 1931

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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MINE EXPLOSIONS, MINE FIRES, AND MISCELLANEOUS ACCIDENTS IN THE UNITED STATES DURING THE FISCAL YEAR ENDED JUNE 30, 1930[1]

By D. Harrington[2] and C.W. Owings[3]

INTRODUCTION

The mining industry is gradually realizing that safety education and safety inspection are economic factors that may not be overlooked as a means of reducing operating costs. Many mine operators, however, have failed to realize the benefits of safety, and the efforts of the more progressive mining companies are offset by the carelessness of neighboring companies when the accident records of a community or a State or the nation as a whole are considered. This tendency is indicated by the data collected by the safety division of the United States Bureau of Mines. During the fiscal year ended June 30, 1930, relatively definite information was secured concerning 34 mine explosions, 24 mine fires, and 29 miscellaneous accidents; these accidents are by no means all of the explosions, fires, and miscellaneous accidents which occurred in the mines of the United States during the period; but the data on the fires and explosions constitute a record of all of those types of accidents that were called specifically to the attention of the safety division, and the miscellaneous accidents include those on which definite, detailed data were obtained by the safety division.

MINE EXPLOSIONS

Of the 34 explosions that were brought to the attention of the safety division, 2 were in rock tunnels, 5 in anthracite mines, and 27 in bituminous mines. All were not major disasters - that is, accidents in which five or more persons were killed; in fact, 11 explosions resulted in no deaths; however, since an explosion is potentially disastrous regardless of the number of lives lost, it is desirable to analyze the cause and other conditions connected with such occurrences if they are to be eliminated ultimately from our mining operations. Table 1 summarizes by States the number of mines using open or closed lights and the assigned causes of the ignitions and mine explosions for the year July 1, 1929, to June 30, 1930.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6419."

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Table 1. - Summary of mine explosions by States, July 1, 1929, to June 30, 1930

	Lights			Total mine-explosions	Fatalities by ignition causes									
					Electricity		Open lights or smoking		Explosives		Unknown		Total	
	Open	Closed	Un-known		Deaths	Igni-tions	Deaths	Igni-tions	Deaths	Igni-tions	Deaths	Igni-tions	Deaths	Igni-tions
Alabama	3	1	-	4	7	1	1	3	-	-	-	-	8	4
California 1/.	-	2	-	2	7	2	-	-	-	-	-	-	7	2
Colorado	-	-	Aban-doned	1	-	-	-	-	-	-	0	1	0	1
Illinois	-	2	-	2	10	2	-	-	-	-	-	-	10	2
Kentucky	1	-	-	1	-	-	16	1	-	-	-	-	16	1
Ohio	2	-	-	2	1	1	0	1	-	-	-	-	1	2
Oklahoma	-	4	-	4	69	2	1	1	1	1	-	-	71	4
Pennsylvania..	1	7	-	8	9	4	1	1	6	3	-	-	16	8
Utah	-	3	-	3	30	3	-	-	-	-	-	-	30	3
Washington ...	-	2	-	2	-	-	-	-	17	2	-	-	17	2
West Virginia.	1	4	-	5	21	3	2	1	-	-	0	1	23	5
Total fiscal year ending June 30, 1930	8	25	1	34	154	18	21	8	24	6	0	2	199	34
Total fiscal year ending June 30, 1929 2/	18	19	1	33	93	18	14	11	26	8	6	1	139	38

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[1] These explosions occurred in tunnels in which methane was being given off and where incandescent lighting was in use.

[2] See Information Circular 6178, issued October, 1929.

Lighting

In 8 of the mines open lights were used; in 25 mines closed lights were worn, at least by the miners; and 1 mine was abandoned. Compared with the fiscal year ended June 30, 1929, there were 10 fewer explosions in open-light mines and six more explosions in closed-light mines during 1929-30. The policy of the Bureau of Mines in considering all coal mines gassy or potentially gassy is substantiated by the explosions in the eight open-light mines, practically all of which were classed as "nongassy," for in each disaster gas was ignited and initiated the explosion, notwithstanding its "nongassy" designation. There is evidence to show that in every one of these open-light mines gas was known to exist or at least was suspected of existing. In at least two of these so-called "nongassy" mines a fire-boss examination was made before the shift of men entered; gas had been ignited by open lights prior to the explosion in two of the mines; and rooms in which the explosion occurred in two of the mines had been "dangered off" or sealed. Undoubtedly there are many more so-called "nongassy" coal mines in which similar conditions exist, and it is equally probable that in the ensuing year there will be explosions in at least eight or 10 of these open-light so-called "nongassy" mines. Until all coal mines are recognized as potentially gassy and our coal mining men take the required action or until legislative action is taken to compel every coal mine to be operated on a closed-light basis there will continue to be gas explosions in so-called "nongassy" mines as well as in mines known to be gassy or even designated as gassy, yet using open lights.

There were 25 or an increase of six explosions in closed-light mines during the past year as compared with the year July 1, 1928 to June 30, 1929. Seventeen of the 25 explosions in closed-light mines were the direct result of using nonpermissible[4] mining equipment; blasting with nonpermissible explosives or disregarding the requirements for firing permissible explosives resulted in six explosions in closed-light mines, and two explosions occurred in supposedly closed-light mines using open lights for some purpose or purposes. There is no question that some operators of coal mines after installing closed lights sit back with a self-righteous feeling of security without attempting to remove open-type electrical equipment that is equally as capable as open lights of igniting gas, or they continue to use fuse in blasting, or they put off shots of black blasting powder while men are in the mine. It is deplorable that such conditions should continue to exist, especially since it seems probable that if the closed-light mines had been operated on a strictly permissible basis - with permissible electrical equipment as well as permissible lights and permissible explosives used permissibly - many if not all of the 177 lives lost in the 25 explosions would have been saved, and the several hundred injured in one manner or other by these explosions would have been spared unmeasurable mental and physical suffering.

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[4] Any device that has successfully passed scheduled tests and is officially approved by the U. S. Bureau of Mines is termed "permissible."

Electrical Causes of Explosions

As in the preceding year, electricity was responsible for 18 explosions, but the number killed increased from 93 to 154, an increase of 61 deaths. Two explosions in tunnels in California caused 7 deaths as compared with none for the preceding 12-month period; in Illinois 10 men lost their lives, in comparison with none for the preceding year; in Oklahoma there was a total of 69 deaths, an increase of 68; in Utah there was an increase from 1 fatality in 1928-1929 to 30 in the past year; West Virginia with a total of 21 deaths showed an increase of 11. In contrast to the above States, Alabama, with 7 deaths, had a decrease of 5; and Pennsylvania, with 9 deaths had a decrease of 56. Pennsylvania, with four explosions from electrical ignitions, three fewer than for the preceding year, again heads the list for the number of explosions from this cause; Utah and West Virginia, with three explosions each, are second in the number of mine explosions of electrical origin, although showing an increase of two and one respectively as compared with the previous year; California, Illinois, and Oklahoma rank third, each having experienced two such explosions; Alabama and Ohio each had one explosion, with electricity as the igniting agency. The number of explosions according to electrical causes is given in Table 2.

Table 2. - Electrical causes of explosions

Causes	Number of ignitions	
	1928-1929[1]	1929-1930
Trolley or cable-reel locomotive	5	5
Nonpermissible mining machine	5	5
Nonpermissible motor	4	3
Nonpermissible shot-firing battery ...	-	[2] 2
Cable nips or blow-out	-	2
Nonpermissible storage-battery locomotive	1	1
Shot-firing line	-	1
Faulty wiring	2	1
Trolley wire	1	-
Electric arc	2	-
Total ignitions	20	18

[1] See Information Circular 6178.

[2] Not included in totals; may have been from overcharged shots and therefore are listed as explosives accidents in Table 1.

A comparison of the electrically caused mine explosions during the past two years shows that there have been 18 during the past fiscal year as against 20 during the previous year (in addition to the 18 explosions of electrical origin in the year 1929-1930 there were two others suspected of having been caused by nonpermissible shot-firing battery, though these two explosions were actually assessed against blasting). In both years there have been five explosions initiated by trolley or cable-reel locomotives and by nonpermissible mining machines. Nonpermissible motors caused only three explosions during the past year as compared with four the previous year.

The nips of a trailing cable on a permissible mining machine caused one explosion and a blow-out of a cable on a similar machine resulted in another explosion. At least two nonpermissible shot-firing batteries caused explosions and an arc made as a shot-firing line was attached to a switch preparatory to firing a charge of compressed gas, resulted in an explosion. No explosions from trolley wire or unclassified electric arc were reported during the year ended June 30, 1930.

Trailing Cables

Trailing cables have been a continual source of danger in coal mines. The bureau has not issued approvals for combination trolley and power cable locomotives, for the reason that these units are considered exceptionally dangerous. Trailing cables are the weak point in the permissible mining machines, although if the instructions for maintenance are observed, there should be small likelihood that a cable will cause an arc. One of the requirements of permissible trailing cables on mining machines has been the use of permissible junction boxes; the failure to comply with this requirement resulted in one explosion. Cables should not be spliced in the mine. Rather spare cables should be readily available, and the defective cable should be brought to the outside where a competent electrician should make the splice and vulcanize the insulation to insure against breakdown at this point. The rule of some progressive companies that whenever a cable becomes definitely worn or breaks down, it should be discarded for underground use, is well worth being adopted by all coal mining companies.

Electrical Shot Firing

Three explosions were initiated by shot-firing batteries or lines. In at least two recorded explosions in which permissible explosives were fired electrically, nonpermissible blasting machines were used, and the evidence strongly points to their having ignited gas. In another explosion noncombustible compressed gas was used to blast down coal, and although the specific instructions for maintaining the permissibility of this blasting device clearly state that only permissible single-shot blasting machines be employed for firing shots with it, the end of the leading cable was attached to an open knife type switch on a 220-volt power line; the resultant arc ignited gas and caused an explosion. In all three instances the shift of men was in the mine or was entering the mine, consequently these accidents emphasize the hazard of blasting while the shift of men is in the mine. It is high time that coal-mine operators realize that it is exceedingly dangerous to blast when men are in the mine; if it seems impracticable to blast from the surface when all men are outside, then blasting should by all means be done by shot firers when everyone else is outside. The sooner the necessity of this precaution is realized, the sooner will needless waste of life be prevented. It should also be recognized that while electrical blasting is in general much safer than other methods, there are numerous hazards connected with electrical blasting, and very definite precautionary measures must be kept in effect at all times if accidents from electrical blasting are to be avoided.

Storage-Battery Locomotives

One explosion occurred in a rock tunnel when the arc from a nonpermissible storage-battery locomotive ignited an accumulation of gas. Undoubtedly because the Bureau of Mines has granted approval for the use of certain types of storage-battery locomotives in gassy coal mines, many mining men have the idea that any storage-battery locomotive is safe in an explosive mixture of gas. No piece of electrical equipment should be used in any atmosphere known to contain dangerous mixtures of gas. Moreover, a nonpermissible storage-battery locomotive is fully as dangerous in gassy places as any other open-type electrical machinery would be, and in some cases is even more dangerous than an open light. To be safe, electrical haulage locomotives should be of the permissible storage-battery type. Studies by the Bureau of Mines have indicated that the operation of this type of locomotive is economical and practical as well as much safer than any other type of electrical haulage locomotive.

Of the 20 explosions initiated by electrical failures, all but one were in closed-light mines. In the one mine, gas had been ignited twice on the day before the explosion and the miners were allowed to use only flash lights or flame safety lamps, hence it was to all intents on a closed-light basis; the fan and pump motors were located on return air and it is presumed that a body of gas drawn over the pump or fan motor was ignited by an arc. The recital of the accidents in closed-light mines stresses the great danger of leaving a task half finished; if a coal mine is sufficiently dangerous to warrant the use of closed lights, then it is so hazardous that all electrical equipment should be permissible and maintained in a safe, permissible operating condition, and ventilation should be maintained fully as well as if open lights were in use.

The value of maintaining electrical equipment in safe operating condition is indicated by a study of the explosions from electrical causes in Pennsylvania. For the year ended June 30, 1930, there was a reduction of 43 per cent in the number of explosions from this cause as compared with the previous year and a reduction of 86 per cent in the number of deaths. This State for a time employed four electrical inspectors and now has at least one full-time inspector whose duty is to see that the electrical machinery in the coal mines of Pennsylvania is in a safe condition. The effect of the electrical inspections is now being shown in the reduced number of major accidents in Pennsylvania coal mines in connection with explosions with ignitions of electrical origin. Every State in the Union which has underground mining operations in which electricity is used should by all means have a sufficient number of competent electrical inspectors to insure a reasonable degree of safety in so far as electrical installations affect underground safety. To date not one State in the Union even approximates this desirable condition.

Open Lights or Smoking

During the fiscal year 1929-1930 the number of explosions resulting from open lights was reduced from 11 to 8, or 27 per cent; however, the number of deaths increased from 14 to 21 or 50 per cent. Alabama heads the list, with three explosions; Kentucky, Ohio, Oklahoma, Pennsylvania, and West Virginia each had one explosion due to open lights. The explosion in Kentucky resulted in 16 deaths. This mine was on an open-light basis, with fire-boss examinations in effect, and the explosion was started by an ignition of gas with an open light. One explosion was initiated by an open light carried by a shot firer, although all other employees were required to wear permissible electric cap lamps. This accident is another of the numerous instances available of the folly of adopting closed lights and allowing open lights and open-type electrical machinery to be used, even if in a restricted section. In another open-light mine two rooms that were found to be giving off gas were sealed, and an official inspecting the seals with an open light ignited gas and caused an explosion resulting in his death. There was no legitimate excuse for using open lights in these coal mines that were known definitely to contain gas, and the loss of the 21 lives from this cause was due to a flagrant disregard of safety. Unfortunately far too many of our mines continue to use open lights even when gas is known to be given off, and only too frequently the substitution of closed lights for open lights in this type of mine must wait until after a disaster has been caused by the open lights.

Explosives

The explosions of gas or dust attributed to explosives were reduced from 8 to 6 during the past fiscal year, and the deaths were reduced from 26 to 24. Washington with 2 ignitions and 17 deaths heads the list, Pennsylvania with 3 ignitions and 6 deaths is second, and Oklahoma is third, with 1 explosion resulting in 1 death.

The causes of these explosions were: Gas ignited by overcharged shot, 4 with 23 fatalities; blown-out shot of black blasting powder, 1 with 1 fatality; and spitting fuse, 1 with no fatalities. These happenings again emphasize the hazard of blasting while the men are in the mine; this practice is particularly dangerous when modern methods of mechanized mining are followed, as frequently the rapid advance allows an added quantity of methane to enter the ventilating current, and these methods generally hinder control of air flow. The increased methane content is often sufficiently increased to form an explosive mixture that may be set off by an overcharged shot, or, if a mild blown-out shot occurs, the gas in the air may convert the "blow-out" into an explosion, as it has been shown definitely that the presence of gas in mine air increases the explosibility of coal-dust.

In the case of the explosion due to the blown-out shot, the shot was charged with black blasting powder, and the shot firer carried an open light for igniting the fuse, although this mine was on a closed-light basis; the use of open flame of any kind in closed-light mines is so manifestly inconsistent that where such a practice is in effect, there is good reason to suspect the existence of numerous other dangerous practices. There is a persistent feeling among mining men who have been blasting with black powder for a number of years that the same grade of lump coal can not be obtained with permissible explosives as with black blasting powder. This contention was largely justified some years ago, but the manufacturers of high explosives have gradually developed permissible explosives from which may be selected grades or brands that will satisfy varying conditions in any coal mine, and it is now possible, by careful use of permissible explosives, to obtain lump coal comparable to that produced with black blasting powder. Therefore there is no legitimate reason for blasting with black blasting powder in coal mines where the coal can be undercut, overcut, or sheared; and more especially is this true of mines using closed lights, which is generally an admission of the occurrence of methane in the mine workings.

An explosion occurred in an abandoned mine and the cause of the ignition was not determined; although it was suspected that trespassers were responsible; so far as known no lives were lost. This incident points out one of the many dangers of leaving abandoned mines open. Annually a number of persons, including children, lose their lives by entering abandoned or small outcrop mines or by falling into unguarded openings to abandoned underground workings. Several lives have been lost through asphyxiation in abandoned mines or workings and several through falls of roof, and now there appears to be a possibility of deaths from explosions in abandoned but unsealed mine openings. Whenever an opening is abandoned or when a test pit has been made and abandoned, the opening should be sealed securely or the pit should be filled in, or otherwise made safe.

Rock-Dusting

Rock-dust had been used to a limited extent in 11 of the 35 mines in which explosions occurred, although the dust was so poorly applied in all but about three of them that it could have had little if any effect on the explosibility of the dust. In one mine, due to the wetness of the face region, it is doubtful if dust entered into the explosion, although rock-dust had been applied to within several hundred feet of the face and if the flame had reached the dusted zone it seems probable that the incombustible content of the dust was high enough to prevent the propagation of the flame. In another mine, although the press reports stated that rock-dusting had stopped the explosion, it seems certain that the wet condition of the dust in the explosion area extinguished the flame, as the rock-dust was in such condition that it is improbable that it could have arrested the propagation of the flame. Although rock-dusting had been done in some parts of one mine, it had been done to such a limited extent that it had no appreciable effect on the explosion. However, if the rock-dusting had been extended to every open accessible part of the mine undoubtedly 20 and probably 22 lives would have been saved. Rock-dusting must

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be a continuous operating routine, like haulage, timbering, or coursing the air. To make rock-dusting effective all entries, rooms, and crosscuts should be thoroughly coated with incombustible dust, the application should be maintained to within at least 40 feet of the face in rooms and entries, and all unsealed and accessible regions whether working or idle should have surfaces well coated with rock-dust. The incombustible content of mine dust should be at least 65 per cent in mines when no gas is present and correspondingly higher if gas is present in the ventilating current.

Time of Day When Explosions Occur

The times of the day at which explosions are most likely to occur, according to data in a publication by Tracy and von Bernewitz in U. S. Bureau of Mines Report of Investigations 2538, are from 3 to 9 a.m. and 3 to 6 p.m. The time of day at which explosions have occurred during the past two years are given in Table 3; the data are far too few on which to base general conclusions, but some interesting facts are disclosed.

Table 3. - Time of day when explosions occurred

Time, a.m.	Number of explosions		Time, p.m.	Number of explosions	
	1928-29	1929-30		1928-29	1929-30
12 to 1	0	0	12 to 1	2	2
1 to 2	2	0	1 to 2	0	1
2 to 3	0	2	2 to 3	3	2
3 to 4	0	2	3 to 4	3	5
4 to 5	0	0	4 to 5	2	2
5 to 6	3	0	5 to 6	1	3
6 to 7	2	0	6 to 7	1	1
7 to 8	4	2	7 to 8	2	0
8 to 9	2	3	8 to 9	3	2
9 to 10	0	2	9 to 10	0	0
10 to 11	2	2	10 to 11	1	0
11 to 12	4	1	11 to 12	0	0

In the early morning hours, that is from 2 to 4 a.m., three of the explosions resulted from ignition of gas by trolley or cable-reel locomotives and one explosion resulted when gas was ignited by an arc from a mining machine. Undoubtedly many of the early morning ignitions are the outcome of no fire-boss examination or of a lax examination or of lack of supervision. The room in which the mining machine referred to above was operating had not been examined for 15 hours prior to the ignition of gas. Evidently there is danger from ignition of gas by mining machines during all the working hours, for during the year ended June 30, 1930, mining machines caused 3 explosions between 8 a.m. and noon and 4 explosions between 3 and 9 p.m. during the same period, locomotives caused 2 ignitions between 8 and 9 a.m. and 2 between 11 a.m. and 1 p.m.; hence it appears that in the morning shortly after the shift starts and the period before and directly after noon are critical times of the day for explosions to be started by electric locomotives. Open lights caused 1 explosion at 7:30 a.m., 2 between 9 and 10 a.m., 1 between 1 and 2 p.m., and 1 between 5 and 6 p.m.; apparently there is no definite time for these ignitions. Ignitions from explosives were restricted to two periods of the afternoon, four occurring between 3 and 4 o'clock and two between 5 and 6 o'clock. These are unmistakably shot-firing periods. This fact clearly illustrates the hazards of blasting while the shift of men is in the mine. The sooner our mining men face the fact that certain kinds of work, liable to cause explosions, may be done only when no other laborers are in the mine, the sooner will the number of persons killed by explosions be reduced. For instance, if blasting had been done from the surface when no one was in the mine, 20 lives would have been saved; if this should not be feasible, shot firers could have blasted when other employees were out of the mine, in which case probably not more than eight lives would have been sacrificed. Similarly, considering the eight explosions started by mining machines, if cutting were done on a nonworking shift, not more than eight lives would in all probability have been lost, where there were actually 41 killed during the past fiscal year.

At a recent gathering of coal mining men, the general experience seemed to be that at least 90 per cent of accidents were caused by old or experienced workmen; however, inasmuch as only about 5 per cent of the miners in this field were inexperienced, the liability to accident was greater among the experienced men. In view of this fact, however, in addition to instructing new men in safe methods of working, it is necessary continually to watch the experienced employee. A consideration of the above classification of causes of accidents, shows that men in the more responsible positions caused most of the explosions in the past year. For instance, 10 explosions were caused by mining machines and only experienced men are allowed to operate these machines; 7 explosions were caused by locomotives, and in general only experienced men are allowed to run locomotives; 2 explosions were caused by electrical machinery, that was under the direct charge of lesser mine officials or bosses; 2 explosions of gas were ignited by open lights worn by foremen and 2 by open lights worn by shot firers. Hence it is apparent that operators should be careful to see that foremen and men in the more responsible underground positions know the safe way of working and that they then obey the safety rules and regulations themselves, in addition to requiring observance of such rules and regulations by the "rank and file" of the workers.

Months in Which Explosions Occurred

It has become almost axiomatic that explosions occur only in the winter months. This idea has probably been handed down from the earlier mining days when drift mines were being worked more extensively than at present. The likelihood of encountering gas is probably not as great in drift mines as in shaft mines, and the effect of the outside atmosphere in depositing or removing moisture from mine surfaces is probably greater in drift mines than in shaft mines. However, so many deep mines are now being worked that often the main working face regions are dry the year round and at the same time more methane is undoubtedly liberated than in the shallower mines. During the past fiscal year no month was free of explosions; Table 4 shows the months in which explosions occurred during the past two fiscal years.

Table 4. - Months in which explosions occurred

Month	Number of explosions		Month	Number of explosions	
	1929	1930		1928	1929
January	8	3	July	3	2
February	3	3	August	8	2
March	4	5	September	1	3
April	0	4	October	2	2
May	3	1	November	2	1
June	1	3	December	1	5

The greatest number of explosions (five) occurred in December, 1929, and March, 1930; there were four in April; and three in September, 1929, and in January, February, and June, 1930. Evidently whenever man's carelessness is such that he provides a source of ignition in the presence of an inflammable mixture of gas and air or in the presence of a dense cloud of combustible dust, there may be an ignition or explosion regardless of the month of the year; the requirements for an explosion evidently were fulfilled in every month in the fiscal year 1929-30.

Table 5. - Comparison of explosion ignition causes, fiscal years 1927-28, 1928-29, and 1929-30

Years	Electricity		Open lights or smoking		Explosives		Unknown		Total	
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
1927-28	14	45.1	12	38.7	3	9.7	2	6.5	31	100.00
1928-29	18	47.4	11	29.0	8	21.0	1	2.6	38	100.00
1929-30	18	52.5	8	23.5	6	18.0	2	6.0	34	100.00

Comparison of Explosion Ignition Causes

Table 5 shows a comparison of ignition causes for explosions during the fiscal years from July 1, 1927, to June 30, 1930. It will be seen that the percentage of explosions attributed to electricity has steadily increased during the past three years; and for 1929-30, 52.5 per cent of all the explosions brought to the attention of the safety division of the Bureau of Mines were of electrical origin. It is high time that cognizance be taken of the fact that explosions from electricity are going to continue to take place and, from the trend of the last three years, in increasing number unless adequate precautions are taken. Wherever such equipment is available, permissible types of electrical machinery should be used and under no conditions should open-type equipment be taken closer than within 500 feet of any coal face which gives off or is likely to give off explosive gas. Also, much closer supervision should be given the installation, operation, and repair of all electrical equipment, wiring, etc., in mines, and certainly ventilation should be maintained at all times as nearly perfect as feasible wherever any type of electrical equipment is used in mines.

It is gratifying to note that the number of explosions from open lights has decreased, during the past three years, from 38.7 to 23.5 per cent of all ignitions reported; this represents a reduction of about one third. However, as has been pointed out, there was a definite knowledge of the presence of gas in every one of the eight mines in which the explosions resulted from the ignition of gas by open lights; the sooner all coal mines "play safe" and eliminate open lights and open-type electrical equipment, the sooner will needless loss of life in so-called non-gassy mines be eliminated; there is no question that any mine known to give off explosive gas even in very small quantities is taking "long chances" in using open lights.

Explosives represented 9.7 per cent of ignitions in 1927-28, 21 per cent the following year and 18 per cent of the ignitions in 1929-30. Thus it is seen that the number of explosions due to explosives (to which attention of the safety division was called) is nearly 100 per cent greater than in 1927-28. Probably half of these ignitions during the past year were directly attributable to nonpermissible blasting with permissible explosives. Two explosions were caused by using nonpermissible blasting units, and when the shots were fired, gas that had been brought to the point of blasting by the ventilating current, was ignited by an arc from the blasting device. In another accident, from two to three charges of permissible explosive had been fired simultaneously in the presence of methane; this was contrary to the published requirements for blasting with permissible explosives. It is impossible to fire an explosive without producing flame, and unless the explosive is firmly confined in holes by incombustible stemming and shots are fired with permissible blasting units there is grave danger of an explosion, especially if methane is present. If more than one shot is fired at a time with delay detonators, one shot may fire a fraction of a second ahead of the other and by releasing gas or raising a cloud of coal dust or by removing part of the burden from one shot and perhaps causing a blown-out shot, thereby, an explosion may result.

One explosion of undetermined origin was reputed to have been caused by a fire in the kerf while a mining machine was cutting coal; the fire may have been due to friction of the cutting chain on impurities in the coal, or it is possible that friction sparks may have ignited the coal-dust in the kerf, but it is more likely that the ignition was of gas and from an electric arc from the mining machine.

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Table 6. - Comparison of explosion fatalities by ignition causes, fiscal years 1927-28, 1928-29, and 1929-30

Years	Electricity		Open lights		Explosives		Unknown		Total	
	Number killed	Per cent	Number killed	Per cent	Number killed	Per cent	Number killed	Per cent	Number killed	Per cent
1927-28	282	82.5	49	14.3	9	2.6	2	0.6	342	100.00
1928-29	93	66.9	14	10.1	26	18.7	6	4.3	139	100.00
1929-30	154	77.5	21	10.5	24	12.0	0	0.0	199	100.00

Comparison of Explosion Fatalities

The fatalities resulting from the explosions brought to the attention of the Bureau of Mines amounted to 199 in 1929-30 as compared with 139 in the previous year and 342 in 1927-28. The increase of 61 fatalities from electrical causes over the previous year, as it happens, is exactly equal to the number lost in the largest disaster of the fiscal year. The deaths from explosions started by electricity (154) represented 77.5 per cent of all fatalities from explosions occurring during the fiscal year. It is significant that 65 of these fatalities or about 42 per cent resulted in explosions in which booster, auxiliary, or underground fans were involved. Open lights were responsible for 21 deaths or 10.5 per cent of the explosion fatalities during the past year, an increase of 7 fatalities over the previous year, although the percentage did not change materially. It is significant that 16, or 76.2 per cent, of the fatalities from open-light explosions were in explosions in which underground booster fans were directly involved. Moreover, 23 of the 24 deaths resulting from explosions caused by explosives occurred in mines where ventilation was controlled, at least in part, by underground fans.

Ventilation and Auxiliary Fans

In spite of the stringent rules supposedly in force in some of the coal mining States, there continue to be ignitions of gas, due primarily to inadequate ventilation which in most cases is attributable to carelessness. Failure to examine workings, or at least to examine them effectively, was in large measure responsible for most of the gas ignitions. In nine of the 34 explosions during the past year, booster, auxiliary, or underground fans were used instead of giving proper attention to standard methods of air coursing. In one mine after an attempt to regulate the air in a split, no examination was made to determine whether the temporary derangement of ventilation had allowed methane to accumulate; a trolley locomotive proceeding relatively close to the face, supposedly in intake air, encountered a gas accumulation and an explosion followed. In another mine a fan was placed underground and provided with an automatic device to shut off power if the fan bearings became overheated; this device operated, shutting off the power while rescuers were attempting to recover the bodies of men injured in an explosion. Without ventilation these men were quickly overcome; they were rescued, however. In still another mine, the method of ventilating a rise working was with an auxiliary fan that was placed considerably beyond the normal ventilating current; the effect was to mix the gas liberated from the face with air so as to form an explosive mixture, and when a piece of electrical equipment of nonpermissible type gave off a spark or arc, the gas was ignited and a disastrous explosion resulted. A hoisting engineer at the beginning of the morning shift in an underground hoisting room, started an auxiliary fan that had been shut down for at least 12 hours; shortly afterwards when the electric hoist was started a body of gas was ignited. In a section of a mine in which ventilation was not adequate, an auxiliary fan was used in a fruitless endeavor to obtain adequate ventilation; it was also supplemented with the exhaust from a compressed-air pipe line; when two or three overcharged shots were fired an explosion resulted, due to ignition of gas that accumulated because of inadequate ventilation.

In 1929-30 there were nine explosions involving underground fans and in which 99 lives were lost. In addition, two explosions, with a total of seven lives lost, occurred in rock tunnels which give off explosive gas. Although the fans concerned in these two explosions were on the surface, metal pipes were used to carry the air from the fans through the tubes to the face of the headings, hence the conditions are in many respects similar to auxiliary fans underground in coal mines. In any event, the fact that 99 or about 50 per cent of the fatalities during the past year were in mines in which ventilation was supposed to be at least partly controlled by underground auxiliary fans, should cause those who have belittled the dangers of auxiliary fans in coal mines to think again regarding the hazards of these fans. There is no doubt that any fan placed underground in a bituminous coal mine is a menace to the safety of all underground workers. There is good reason for the belief that at least half of the lives lost in explosions in the mines of the United States during the past fiscal year might have been saved if attention had been given to the proper ventilating of coal mines by means of fans placed on the surface and suitable fireproof air-tight stoppings, doors, and line brattices rather than dependence placed on auxiliary underground fans and tubing to bring an adequate amount of circulating air to every gassy face.

Improper ventilation as a direct result of the mining method in two mines, one of which used mechanized loading exclusively and the other of which used mechanized loading in the section on which the explosion started, emphasizes the need of exercising exceptional care in ventilating workings in mechanized mines where mechanical contrivances operated by electricity are used at or near gassy or dusty faces. The rapid advance of the coal face in up-to-date mechanized mining exposes fresh surfaces that are likely to liberate both dust and gas at a higher rate and in larger quantities than does the slower hand method. The rapid advance increases not only the dust but even to a greater degree the gas hazard, because in many mines the intake for one face is the return from an adjacent face that may have given off methane in dangerous quantities, with consequent vitiation of the "intake" air that later on may pass over arcing electrical equipment and thereby cause an explosion.

Table 7. - Comparison of lighting in mines where explosions occurred, fiscal years 1927-28, 1928-29, and 1929-30.

Year	Open lights		Closed lights		Lighting unknown		Total	
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
1927-28	14	45.1	15	48.4	2	6.5	31	100.00
1928-29	18	47.4	19	50.0	1	2.6	38	100.00
1929-30	8	23.5	25	73.5	1	3.0	34	100.00

Comparison of Lighting in Mines

Table 7 compares the number of explosions during the past three fiscal years in closed-light mines with those in open-light mines. It is seen that the explosions in open-light mines constituted only 23.5 per cent of the total as compared with 47.4 per cent the previous year and 45.1 per cent in 1927-28. The explosions in closed-light mines increased from 50 to 73.5 per cent; two of these were in rock tunnels, in which incandescent lights were used exclusively for illumination. It is of interest to note that one of the tunnel explosions was suspected of having been initiated by an exposed filament of a broken electric-light bulb; the use of the usual or ordinary type of incandescent lighting at or near faces or places which are or are likely to be gassy or dusty is dangerous in the extreme.

There were 21 fatalities from eight explosions in open-light mines (as well as an additional fatality when the use of an open light to fire shots in a closed-light mine caused an explosion) as compared with 177 from 25 explosions in closed-light mines, indicating that the explosions in closed-light mines are more likely to cause greater damage and result in a larger loss of lives than in open-light mines. This extra damage from explosions in closed-light mines is the logical result of the neglect of ventilation so often found after closed lights have been installed. There is no question that there is a definite tendency to relax in ventilation after closed lights have been installed, and there is also no question that explosions will continue to occur until our mines carry into effect not one or a few of known safety provisions but rather keep all of those good practices in effect at all times.

Barricades

The Bureau of Mines instruction in methods of protecting against gases after explosions evidently has had some effect, for in the 34 explosions during the past fiscal year, at least five groups of miners in four mines barricaded themselves and probably at least 27 lives were saved in this manner. After a coal-mine explosion a group of 12 men was sent by a mine official into one section of the mine, where they erected two canvas brattices and kept out a sufficient amount of the gas so that they were not affected; these men were rescued later. Another group of five men barricaded themselves behind a canvas brattice and stayed there until rescued, whereas the other men in that section who tried to escape were overcome by the afterdamp and died; the man who was responsible for the erection of the barricade had a short time before seen a Bureau of Mines moving picture film showing how to erect a suitable barricade, and he put this knowledge to good use. Unquestionably the best method available to those who are alive and trapped in a mine after an explosion or at times of mine fire, is to barricade themselves and await rescue with restoration of ventilation or through other methods. Bureau of Mines Miners' Circular 25 gives many pertinent data concerning barricading, and its contents should be carefully read and understood by every person who goes into any kind of underground workings.

MINE FIRES

Mine fires generally do not cause as much comment and concern as an explosion, although in reality they may be very dangerous in themselves, and if coal mine fires are not handled carefully, they are very likely to result in explosions. On the other hand, mine fires may be prevented from becoming serious if ordinary care is taken and if adequate provision is made to combat fires. However, a comparison of the number of mine fires that have been brought to the attention of the safety division of the Bureau of Mines during the past two years indicates that there is a decided increase in mine fires, due, undoubtedly, to increased carelessness of our mining people. During the fiscal year 1928-29 the attention of the Bureau of Mines was directed to 15 mine fires in the United States. Of this number 13 fires were in coal mines and two in metal mines. In the fiscal year ended June 30, 1930, at least 24 mine fires were reported, 19 of which were in coal mines, 4 in metal mines, and 1 in a railroad tunnel. The coal-mine fires resulted in four deaths and the metal-mine fires in one fatality; no lives were lost in the tunnel fire.

Distribution of Mine Fires

Kentucky, with four fires, heads the list in number of ignitions; Ohio, with three fires, ranks second; California, Indiana, Michigan, Pennsylvania, and West Virginia each had two fires; and Colorado, Idaho, Illinois, Oklahoma, Utah, Washington, and Wyoming had one fire each. Ohio had 2 fatalities from mine fires, Kentucky had 2 deaths, and Michigan had 1 death. No deaths were reported in connection with mine fires in the other States. Table 8 summarizes data on mine fires during the year 1929-30.

by States, July 1, 1929 to June 30, 1930

States	Lights			Total	Fatalities by ignition causes									
					Electricity		Open lights or smoking		Explosives		Mis-cellaneous		Total	
	Open	Closed	Un-known		Deaths	Igni-tions	Deaths	Igni-tions	Deaths	Igni-tions	Deaths	Igni-tions	Deaths	Igni-tions
California ..	1	-	None	2	0	1	-	-	-	-	0	1	0	2
Colorado	-	-	Out-crop	1	-	-	-	-	-	-	0	1	0	1
Idaho	-	-	1	1	-	-	-	-	-	-	0	1	0	1
Indiana	1	-	1	2	-	-	-	-	0	1	0	1	0	2
Illinois	-	1	-	1	0	1	-	-	-	-	-	-	0	1
Kentucky	1	1	2	4	0	2	2	1	0	1	-	-	2	4
Michigan	2	-	-	2	-	-	1	2	-	-	-	-	1	2
Ohio	2	1	-	3	2	2	0	1	-	-	-	-	2	3
Oklahoma	-	1	-	1	-	-	0	1	-	-	-	-	0	1
Pennsylvania.	-	1	1 abandoned	2	-	-	0	1	0	1	-	-	0	2
Utah	-	1	-	1	0	1	-	-	-	-	-	-	0	1
Washington ..	-	1	-	1	0	1	-	-	-	-	-	-	0	1
West Virginia	-	1	1	2	0	1	-	-	-	-	0	1	0	2
Wyoming	-	-	1	1	-	-	-	-	-	-	0	1	0	1
Total, fiscal year ending June 30, 1930	7	8	9	24	2	9	3	6	0	3	0	6	5	24

Electrical Causes of Mine Fires

Of the mine fires with which the safety division was in contact during the year ended June 30, 1930, at least nine were reported to have been of electrical origin. The causes of mine fires due to electricity and the fatalities resulting therefrom are given in Table 9, following:

Table 9. - Electrical causes of mine fires, fiscal year ended June 30, 1930

Causes	Fatalities	No. of fires
Electric heater ignited lagging	0	1
Trolley wire	2	6
Cable ruptured or blown-out	0	2
Total	2	9

One fire occurred in a metal mine when an electric heater, used to warm the room in which the electric hoist was located, was left turned on at night while the shift of men was out of the mine. Lagging nearby became overheated and, as there was but one entrance to the mine, the acrid fumes prevented men, who had no protective devices, from entering the mine to fight the flames. When the bureau's representative arrived with respiratory devices, the fire was quickly controlled. This fire illustrates a hazard that is common to many mines, namely the use of electric heaters of the exposed type in mines and on coal-mine tipples; these heaters are often left unattended and, as in this case, they may be left turned on, when the workmen go off shift. This fire also shows the hazard of having only one opening to a mine or a section of a mine.

Eight of the nine fires caused by electricity were in coal mines. Six fires, resulting in two fatalities, were caused by trolley wire. In one mine the trolley wire came in contact with the wooden door frame of a trap door and ignited it; as the door was on the main haulage road it might have resulted seriously. One fire was caused by a fall of roof, which short-circuited the trolley wire; due to poor bonding, resulting in weak power at working faces, the overload cutout had been set to operate at such a high power demand that the short-circuiting of the trolley wire failed to cause the power to be shut off. This fire exposes a practice far too common, and unless adequate precautions are taken to prevent such dangerous methods of operating mines, many fires are very likely to result.

Life was lost in a mine fire which started when a wrecked trip of cars short-circuited the trolley wire; this fire threatened the lives of 94 men, and it was only through the cool-headedness and knowledge on the part of some mine officials of the right thing to do in case of fire that 89 lives were saved. A group of 22 men barricaded themselves in one section of the mine;

another group of 27 men barricaded themselves between two doors, forming a natural air lock, by filling in the cracks around the doors; 40 others protected themselves by short-circuiting the air and by making a door practically air-tight. One of these men was brought to the surface in a weakened condition. As the fire was on the main haulage and on intake air, the fire was fought without the use of oxygen breathing apparatus or gas masks, but when some men who were rescued reported men in distress in a return airway, the rescuers proceeded to their assistance without protection and, although no one was fatally affected, several suffered from exposure to the smoke fumes.

Two fires were caused by cables "blowing out" or becoming overheated. A cable in a drill hole blew out and caused a fire that was fought successfully by the company's crews. Every precaution was taken to protect the lives of the fire-fighters; a high official of the company stated afterwards that the training given the men by a representative of the Bureau of Mines, who instructed them in the course in advanced mine-rescue training, was of great help in controlling this fire. The other fire resulted when a mining-machine cable left connected to the power line at the end of the shift became overheated and caught fire. No fatalities resulted from these fires, but the property loss in both was heavy and in one was particularly heavy.

There are several lessons to be learned from the fires caused by electricity. As in the case of mine explosions, electricity is becoming a most prolific cause of mine fires. Short-circuiting of the trolley wire is the outstanding cause of this type of fire; trolley wires, in fact all bare power wires, should be kept as far from the working faces as possible, and it is advisable, wherever feasible, to use permissible storage-battery equipment and eliminate the trolley wire from the mine or from as large a part of it as possible; at present permissible storage batteries are used successfully for locomotives, mining machines, pumps, etc. Care should be taken to install electric wiring in a safe manner, always using adequate insulators to support it, and the same care should be given to protecting a ground or return wire as the so-called "hot" wire. The pernicious habit of nailing wires to wooden supports should be prohibited in all mines--metal as well as coal--and where at all feasible, power should be "cut out" of wires in mines or parts of mines when men are not present or supervision available at frequent intervals.

The fire in which 89 miners saved their lives by barricading themselves in pure air again brings to the attention the advantages of instructing all men in methods of protecting themselves against accidents and of giving the Bureau of Mines course in advanced mine-rescue training giving data in the safe handling of mine fires and explosions to the officials and more responsible employees at all mines, metal as well as coal.

There is also a definite need of instructing all men in, at, or around mines, in the dangers of rushing into a mine or confined place after an explosion or during a fire in an effort to rescue men; in many instances most of those in the mine are dead, and in any case it is very foolish to go into mines at time of fire or explosion without taking the precaution to secure adequate protective devices and to coordinate the work of those present. The men in one fire, as noted previously, endangered their lives by entering the smoke-filled return airway without oxygen-breathing apparatus or other adequate protection from irrespirable gases. At another mine fire three officials without respiratory protective equipment followed along the main haulage, which was the return airway, until they deemed it unsafe to go farther and then reached the surface in a dazed condition; one of the men stated that he did not remember climbing the slope to the surface. Far too many chances are taken immediately after occurrence of a fire or an explosion, and "making haste slowly" is good policy ultimately.

Fires Caused by Open Lights

Open lights were responsible for six mine fires during the past year. The term "open lights" is used in its broader sense of open flames, including cigarettes, matches, etc. The classification of fires from this cause is listed in Table 10. The fuel tank of a gasoline motor used to run an underground pump was being filled by a man wearing a carbide light; the gasoline vapors were ignited by the lamp, and during the resulting fire two men lost their lives. Two fires were caused probably by smoking, although one of these fires may have been started by the flame of a miner's carbide lamp igniting waste or waste material in a locker at a pump room; in any event, as soon as smoke was smelled one man hurried to the locker several levels above, as if he suspected the fire of having started at the locker room; this man lost his life.

In connection with the rescue of two men at a mine fire, a valuable lesson was taught; all men were told to wait for the cage to haul them to the surface, but two men started to climb the ladders and became weakened by the smoke fumes, as the ladderway was on the return air. Fortunately the man cage was equipped with an electric signal system, operable from the cage; by means of signals the cage was moved slowly up and down the shaft, and finally it was stopped opposite the point where the men had been compelled to stop in the ladder compartment; a hole was cut in the wooden partition and the men were rescued. If the cage had not had the signal operable from the cage, it is doubtful if the men would have been rescued. The cause of another fire in a metal mine in this district was attributed to cigarettes or open lights, and now most of the metal mining companies in the entire region have adopted a "no-smoking" rule, although a number of companies having had similar fires had already adopted a "no-smoking" rule prior to these two fires. One fire was reported to have resulted from boys building a fire in an abandoned mine.

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Table 10. - Fires caused by open lights and smoking

Cause of ignition	Fatalities	Number of fires
Gasoline ignited underground	2	1
Smoking	1	2
Gas ignition	0	2
Miscellaneous	0	1
Total	3	6

There are many hazards from open lights in mines, whether metal or coal. The fire hazard is very real in metal mines, and several are now experimenting with the use of the safer permissible electric cap lamps. These lamps give fully as much light as most of the open lights and, in addition to this feature, it is not necessary to regulate the water feed and refill them at frequent intervals, as is the case with the usual present-day open lights. There is a tendency in many metal mines to allow refuse, such as boxes and paper, to accumulate in parts of a mine; if open lights or smoking are allowed, such accumulations are readily set on fire by the flame of a lamp or by a match or a cigarette, and numerous fires in metal mines have been ascribed to this cause in late years. The foolish habit of lighting a piece of paper and throwing it down a chute, to ascertain the height of ore in the chute has lead to several disastrous fires; open lights coming in contact with timber as a miner works or bends over in a timbered section have caused many fires. It is of almost as much importance that open lights and smoking be prohibited in metal mines as in many coal mines, because, added to the ordinary danger attendant on such fires, the lack of adequate escapeways from many metal mines or parts of them has in a number of instances lead to loss of many lives at time of mine fire.

Fires Caused by Explosives

Three fires to which the attention of the safety division of the Bureau of Mines was called during 1929-30 were caused by explosives. Two of the fires resulted from shots of black blasting powder, and one fire was caused when a "spitter" fell or was blown onto the floor of a coal mine and ignited the loose coal. All of these three fires were caused by the use of black powder in coal mines. The hazard of using this explosive in coal mines has so many ramifications that it is inconceivable why so large a proportion of our mines persist in clinging to so dangerous an agent.

Miscellaneous Causes of Mine Fires

Six fires were started by miscellaneous causes; two fires originated by spontaneous firing; three fires were caused by transmission of fire in surface structures to the shafts; one fire was said to have been caused by friction of the cutter bar of a mining machine on the impurities in a coal bed. To avoid deaths in mines due to fires in surface structures, it is becoming a well-recognized practice of many up-to-date mining companies to provide fire doors at the entrances to mines. A fire door should be provided at the collar of every shaft or other mine portal, and these doors should be capable of being closed automatically.

Lighting in Mines

Table 8 lists the lighting in the mines in which the fires occurred. Seven fires were in open-light mines, eight were in closed-light mines, and nine were in abandoned mines, in the outcrop coal, or where the lighting used was unknown. In other words, the fires were distributed about equally between open and closed light mines, with reference to those mines in which the lighting was definitely known. One fire was in a railroad tunnel, 4 fires were in metal mines, and 19 fires were in coal mines. Of the coal-mine fires, 4 were in open-light mines, 8 were in closed-light mines, and 7 were in mines in which the lighting system is unknown in so far as available information goes. At least 3 (and very probably all 4) of the metal-mine fires were in open-light mines. Of the fires caused by electricity, 3 were in open-light mines and 4 were in closed-light mines; 4 fires originating from open lights occurred in open-light mines, and 1 fire in a supposedly closed-light mine was very definitely assessed against an open light; 2 fires from explosives were in open-light mines and 1 was in a closed-light mine. There is absolutely no question of the advisability, from a safety point of view, of placing all mines on a closed-light basis and requiring the use of such equipment that, under proper maintenance, will not cause sparks or arcs capable of starting a fire.

MISCELLANEOUS MINE ACCIDENTS

The accidents generally called to the attention of the safety division of the Bureau of Mines are those in which help is needed, such as the use of oxygen breathing apparatus in fires, explosions, or bursting of gas cylinders or other occurrences connected with gas or liquid-containing devices. The 29 accidents of a miscellaneous character called to the attention of the safety division of the Bureau of Mines in 1929-30 are summarized in Table 11, and are classified according to their character. Some of them were not in mines, but they point out lessons that may serve to reduce mine accidents. This list is not complete, and the percentages of any one kind of accident according to the table is no criterion as to the number of such accidents occurring annually.

Table 11. - Summarized data on miscellaneous mine accidents, by States, fiscal year July 1, 1929 to June 30, 1930

State	Electricity		Open lights		Explosives		Hoisting		Fall of rock		Unclassified		Total	
	Killed	No.	Killed	No.	Killed	No.	Killed	No.	Killed	No.	Killed	No.	Killed	No.
Calif.	1	1	-	-	1	1	-	-	5	1	-	0	7	3
Colo.	-	-	-	-	-	-	-	-	4	1	1	1	5	2
Ind.	-	-	1	1	-	-	-	-	-	-	-	-	1	1
Ill.	-	-	-	-	-	-	-	-	-	-	1	1	1	1
Ky.	1	1	-	-	4	1	1	1	4	2	2	1	12	6
Mass.	5	1	-	-	-	-	-	-	-	-	-	-	5	1
Mich.	-	-	-	-	6	1	-	-	-	-	-	-	6	1
Minn.	-	-	-	-	4	2	-	-	-	-	-	-	4	2
N. Y.	-	-	-	-	2	1	-	-	-	-	-	-	2	1
Ohio	-	-	-	-	-	-	-	1	-	-	-	-	0	1
Penn.	-	-	-	-	1	1	-	-	10	3	9	3	20	7
Utah	-	-	-	-	-	-	1	1	-	-	-	-	1	1
W. Va.	-	-	-	-	6	1	-	-	-	-	-	-	6	1
Tenn.	-	-	-	-	2	1	-	-	-	-	-	-	2	1
Total	7	3	1	1	26	9	2	3	23	7	13	6	72	29

Accidents from Electricity

Three accidents were reported that were suspected of having been caused by electricity. At a gasoline plant that had been put in operation before construction was completed, one of the tanks of gasoline started to leak; in the resulting fire the flames spread over a considerable area, and the burning fluid overtook a man who was attempting to escape and caused his death. As is so frequently the case where construction is in progress, the electric wiring was not in first-class condition, and it is believed that when the tank burst, the gasoline vapors came in contact with defective electric wiring or transformers, and an arc or spark ignited the gas fumes.

Five men were killed in a premature explosion of dynamite in a rock tunnel. At the time of the explosion it was thought that a piece of rock had fallen on the primed cartridges and caused the explosion, but later a miner, while carrying a cartridge of dynamite primed with a delay detonator, heard a hiss and threw the cartridge from him; the cartridge exploded in the air. The man was carrying an unapproved type of hand flash light; upon experimenting later with the lamp, it was found that when the button was depressed, if one leg wire of a detonator was touched to the case and the other to the button simultaneously the detonator exploded every time the test was made. This concrete example of detonation by a nonpermissible flash light shows that the explosion in which the five men were killed might have been caused (in fact, probably it was caused) by a flash light, as the man carrying the explosives at the time of the former disaster also had a flash light similar to the one tested.

This accident indicates that the Bureau of Mines is amply justified in recommending that only permissible flash lights be used in atmospheres that are or may become gassy or when explosives are being handled; in fact, there is no good reason why the permissible flash light should not be used exclusively whenever a flash light is taken into any kind of mine.

A miner, while pushing a car into a room, came in contact with a piece of bare machine wire and was electrocuted. The reports of State mine inspectors show that many similar accidents are occurring every month. There were 11 fatalities in the coal mines of Alabama in 1929 from contacts with electric wires, according to F. E. Cash and H. B. Humphrey in Bureau of Mines Information Circular 6354, issued in September, 1930. The fatalities from contacts with electricity in West Virginia mines during 1929 were 22, according to monthly reports by the State department of mines; for the 12-month period ended June 30, 1930, there were 18 deaths from electricity. Undoubtedly reports from most of the other mining States will show a considerable number of deaths in mines from contact with electricity. Some of the reasons for fatalities from electricity are that the trolley wire or machine wire is hung low, that the power lines are not guarded where men are forced to pass under or near them, that wires are usually uninsulated or poorly insulated, and that carelessness is displayed in hanging power-carrying wires in mines or on the surface at mines. It is therefore advisable to require all power wires or cables to be well supported on adequate insulators, and where feasible none but well-insulated cables be used, if it is necessary to transmit power into a mine. Certainly safety demands that all electric wires should be well guarded at points where men or animals must pass under or close to them, unless the wires are 7 or more feet above the rail. (The generally accepted figure of 6½ feet above the rail does not always afford protection to a tall man with a lamp in his cap.) Furthermore, all power carrying wires less than 6½ feet above the rail should be adequately guarded throughout their length. This may seem a drastic recommendation to some of our coal mining men, but it is being done in a number of metal mines, and in the face of the increasing number of fatalities from contact with electric wires in coal mines this precaution should be taken. If permissible storage-battery mining equipment is substituted for the present equipment continuously receiving power from electric wires, the probability of occurrence of fatalities in mines from contacts with wires will be greatly reduced. Although it is inadvisable to advocate halfway measures in safety as an expediency, where complete storage-battery power can not be used throughout the mine, the danger of deaths from contact with power lines will be greatly reduced by restricting power wires to the main intake haulage roads, using permissible storage-battery locomotives and mining machines, providing manways--preferably on intake air--for the travel of men, and enforcing the rule that men shall travel the manways exclusively. The trolley system is dangerous in mines, coal or metal, and its use should be greatly abridged or very carefully safeguarded if our mines are to be kept even fairly free of explosions, fires, and deaths by contact with bare wires.

Open Lights and Explosives Accidents

One accident from open lights was reported at an open-pit mine. The carbide lamp carried by a boy ignited two kegs of black blasting powder, and the resulting explosion killed one man and severely injured another. Apparently open lights as well as black blasting powder are hazardous wherever mining is done--on the tipples, in open pits, underground, or elsewhere.

Nine miscellaneous explosives accidents, resulting in 26 fatalities, were brought to the attention of the Bureau of Mines. The comparison of causes and number killed are contained in Table 12.

Table 12. - Comparison of causes of miscellaneous explosives accidents, fiscal year ended June 30, 1930

Cause	Fatalities	Number of accidents
Explosion in automobile truck	1	1
Tamping explosive	8	2
Striking misfired shot	6	1
Short fuse or igniter fired shot ...	1	1
Crimping detonator	6	2
Asphyxiation from explosives fumes..	2	1
Transporting explosives	2	1
Total	26	9

One fatality resulted when explosive detonated in an automobile truck on an open highway. The exact cause of the ignition and explosion was not determined, but there may have been several causes. When transporting explosives, only one kind of material should be hauled at one time; detonators or fuse should not be hauled in the same truck with explosives; electric wiring should be in conduit; the exhaust pipe should be protected from the truck body by a sheet of asbestos or other heat-resisting material; the exhaust should be protected with a flame baffle; and the explosives should be protected from the sun's rays. (For more detailed information see Information Circular 6330.)

Two premature explosions occurred in open-pit mines while holes were being loaded: (1) Nitrostarch was being loaded into a hole and tamped by allowing a lead weight to fall several feet, when the charge exploded; (2) while a hole was being charged with liquid oxygen explosive, a cartridge "stuck" and when it was ~~being~~ "fished out" with a bronze hook, the charge detonated. Each of these accidents resulted from careless handling of explosive. Often an "experienced" man becomes indifferent to the hazards of handling explosives, and accidents usually result.

Six men were killed when the foreman of a gang working in a rock tunnel failed to observe that a charge of explosives had misfired and started to use a pavement breaker. The steel point of the breaker evidently came in contact with one of three misfired shots and caused it to detonate, killing six men and injuring a like number. This appeared to be a case of carelessness. By all means a man in charge of a group of workmen should take every precaution to prevent drilling into a misfired shot, and if a careful search had been made in this case, undoubtedly the explosion would not have occurred.

It is presumed that one miner lost his life from a premature explosion caused by a short fuse or a shortened igniter which fired the charge before he could get out of the room. Six persons were killed when several boxes of explosives detonated; the cause probably was the exploding of a detonator when it was being crimped to a piece of fuse by a man using the back of his knife. An unnecessary risk is taken when explosives are fired with fuse; electric detonators or igniters may be used with greater safety than fuse in coal mines and in at least some metal mines. There will continue to be the annual toll of lives lost from premature explosions as long as fuse is used. Two men lost their lives in a cave into which fumes from a blast of dynamite had penetrated through a crevice in the intervening rock; this was an unusual accident, but it serves to illustrate the danger from fumes given off in blasting. Even where it might be supposed the explosives other than permissible explosives would be safe, the poisonous fumes given off in blasting must be considered. Unless adequate ventilation is provided, the fumes from explosives may linger for a considerable period; in the accident cited the blast had been fired about three hours before the men entered the cave.

There were three hoisting accidents. A hoisting engineer allowed the cage to "drift," and when he tried to apply the brake, the brake slipped from his hand, allowing the cage to continue to descend and strike the bottom. Another accident resulted when a temporary cage in a new shaft caught on the side construction and dumped one man from the platform. Every cage should be equipped with adequate safety catches, and the hoisting engine should be regulated by an overwinding-overspeeding device that will work automatically.

Fall-of-Rock Accidents

Twenty-three lives were lost in seven fall-of-rock accidents. Inasmuch as only one or two men generally are killed at one time in such accidents, the causes of the unusual accidents have been summarized in Table 13.

Table 13. - Causes of fall-of-rock accidents, fiscal year July 1, 1929 to June 30, 1930.

Cause of Accident	Fatalities	Number of accidents
Roof loosened by blasting	8	3
Cave-in	15	4
Total	23	7

The accidents have been classified into those resulting from roof loosened by blasting, in which eight lives were lost in three accidents, and into cave-ins, in which 15 lives were lost in four accidents. In one mine that had resumed operations after being idle for about six months, the overlying rock fell in a stope and killed five men; it is believed after the mine was idle for so long a period that when blasting was resumed the roof became weakened and fell without enough warning to allow the men to escape. Two accidents occurred in the same mine within three months; before each accident the roof had been blasted, and several days later it became loose and fell while men were sitting under it; three men were killed in one accident and one man in the other. Perhaps the outstanding accident occurred when men, extracting pillar coal and not having timber delivered to them after several requests, secured some posts from nearby workings, but because of not having enough posts to make the place safe, were caught when the roof fell with little warning; three men were killed, one was injured, and one escaped. This accident is representative of many similar ones in which only one or two men are caught. Every effort should be taken to keep workmen supplied with proper timber and a sufficient amount of it within a reasonable distance of the place where the timber must be used. The lessons to be learned from these accidents are: After a place has been idle, extra precautions should be taken to support the roof; after blasting, the roof should be examined carefully and tested for vibrations by placing the fingers of one hand on the roof while tapping it a sharp blow with a solid metal or other suitable bar; when working near the surface, especial care should be taken after a rain to provide against a run of water-soaked ground; and by all means miners should be kept provided with adequate timber of a kind, size, and approximate length suitable for the place to be supported.

Unclassified Accidents

Six accidents causing 13 deaths are unclassified. Two of the accidents, resulting in eight fatalities, were industrial explosions in plants using blower fans. An explosion occurred in a bronze plant, and the cause of the explosion was undoubtedly a fire found burning in a crushing room. Fans had been placed in the roof to exhaust the excess dust, and it seems possible that the draft created by this fan may have contributed to the explosion. Four explosions of zinc-dust occurred in a plant within a period of three weeks; the fine material was collected in an air separator, and in each instance when a fire resulted, probably from electric sparks or arcs, the forced draft from the separator fan increased the intensity of the flames. These explosions in bronze-dust and zinc-dust were probably made possible through the action of fans in increasing the flames of fires. Metals, as well as other quickly oxidizable materials, are capable of exploding violently when comminuted. Therefore, permissible-type dust and gas proof motors should be used to run all machinery wherever these dusts are used, made, or may accumulate; and in addition, care should be taken to prevent the occurrence of stray electrical currents, static sparks, etc.

The control of a gas well brought out some interesting points of safety. The area surrounding the well was filled with gas and when the men were working near the well they had to use hose masks with 100-foot lengths of hose. The use of ordinary gas masks would have been extremely dangerous as the concentration of gasoline fumes may have become so great that there would not have been enough oxygen present to support life and the wearers of gas masks might have become unconscious in a short time. While the oil well above mentioned was being brought under control, all sources of sparks, such as matches, patent cigar lighters, smoking materials, electric equipment, and even steel shoes on mules were prohibited within a radius of several hundred feet of the well. It may be well to cite an accident that occurred recently, in which a man wearing a gas mask was lowered into an empty gasoline tank. Presumably the gasoline vapor was concentrated, for no sooner had the man reached the bottom of the tank than he signalled to be hoisted and upon reaching the surface he collapsed and died before medical aid reached him. This is but one of numerous accidents of this kind which occurred during the past few years; it must be borne in mind that gas masks can not be worn with safety in an atmosphere deficient in oxygen, therefore they should not be worn in a confined space where there are likely to be large percentages of irrespirable fumes, such as in tanks used to transport oil, or in gas tanks.

The need of first-aid training by all industrial workers was shown in an accident on a highway. Several men were using a welding outfit when suddenly the acetylene cylinder ruptured with explosive force. Part of the metallic base severed a leg from the body of one man and as none of his fellow workmen knew how to stop the bleeding, they had to watch him bleed to death before a doctor could be summoned. Very probably if these men had been trained in first aid they could have saved the injured man's life.

This brief discussion of some miscellaneous accidents brought to the attention of the personnel of the Bureau of Mines safety division has brought out the fact that many of the safety practices that every mining man should know are of considerable value in work outside of the mining industry. Safety is a universal necessity, and every industrial worker should heed the warnings of those interested in safety and should accept every opportunity to receive safety instruction. Whatever we may learn of safety in our daily work may often be applied to other work and through safety knowledge we may be able to help someone else.

CONCLUSIONS

The record of mine accidents during the past fiscal year is not a good one. While there has been a slight reduction in the number of explosions in open-light mines, there has been a corresponding increase in the number of explosions in closed-light mines. Although four fewer explosions were reported to the safety division of the Bureau of Mines this year than for the previous year, fatalities were 35 per cent higher. A slight reduction in accidents for a limited period is no criterion that accidents have ceased and that it is safe to relax in vigilance, because a real reduction in accidents is generally only the result of stringent continued enforcement of safety rules, regulations, and practices at all times. In any event, with a record of 199 lives lost through explosions there is no justification for a relaxation in our efforts to obtain freedom from this type of accident, which is by far the least excusable now occurring in mines. If the well-known and readily available precautions are taken, explosions are absolutely preventable. Many of the explosions in which no lives were lost or one or two men lost their lives may have proved disastrous under different conditions; at the time of several of the explosions listed in this paper there were only one or two persons in the mine, and all underground were killed; if these explosions had occurred when the working shift was in the mine the number of fatalities for 1929-30 would have been several times larger than it was. To reduce mine accidents, there must be a concerted effort on the part of all mining men at all times.

The salient points brought out in the study of the accidents which have been brought to the attention of the safety division of the Bureau of Mines for the year ending June 30, 1930, are essentially as follows:

Mine Explosions

1. There were 34 explosions, 27 in bituminous mines, 5 in anthracite mines, and 2 in rock tunnels, during the past year, as compared with 38 for the previous year.

2. Explosions took 199 lives in the year ended June 30, 1930, as compared with 139 in the previous year.

3. Eight explosions were in open-light mines as compared with 18 the year before; 25 explosions were in closed-light mines as compared with 19 in 1928-29. As evidence shows that gas was known to exist in all of the open-light mines, in which these explosions occurred, it would appear that the bureau is justified in classing all mines as potentially gassy.

4. There was no change in the number of explosions (18) from electricity as compared with the previous year, but the number of fatalities increased from 93 in 1928-29 to 154 in the past year. Explosions started by electricity were responsible for 77.4 per cent of all of the fatalities from explosions during the past fiscal year.

5. Pennsylvania, with four explosions, ranks first in the number of explosions caused by electricity during the year; and Oklahoma, with 69 fatalities, ranks first in the number of deaths from this class of explosions.

6. Twenty explosions from electricity (if the two explosions probably started by nonpermissible shot-firing batteries are included) occurred in each of the last two years; trolley locomotives and nonpermissible mining machines again head the list of electrical causes of explosions, each being responsible for five explosions in each of the two years. Explosions were caused by

broken incandescent light bulb, by nonpermissible mining machine using 250 volts, by nonpermissible mining machine using alternating current, by mining machine nips, by ruptured mining machine cable, by nonpermissible storage-battery locomotive, by nonpermissible pump motor, by nonpermissible fan motor, by blasting wire, by nonpermissible blasting device, by nonpermissible electric hoist, by trolley locomotive, and by cable-reel locomotive. Some of the causes cited were responsible for several explosions.

7. Two explosions resulted from firing shots of permissible explosives with nonpermissible blasting machines, the electric current of the machines in each explosion being assigned as the probable source of ignition.

8. There were eight ignitions or a reduction of 27 per cent, and 21 fatalities or an increase of 50 per cent, from open lights in 1929-30 as compared with the previous fiscal year.

9. Explosives cuased six ignitions and 24 deaths during the past year, as against eight ignitions with 26 deaths during the previous year.

10. Rock-dust was used in at least 11 of the mines in which explosions occurred, but it was effectively applied in only three mines. The rock-dust undoubtedly played an important part in stopping three explosions, but it is questionable if the slight amount of rock-dusting done in the other cases was of material aid in preventing loss of life or of property.

11. Four ignitions of gas occurred in the early morning hours of the working shift, the accumulations of gas presumably being undiscovered through lax examination of workings; much of this lax examination of workings is due to the fact that the fire boss does not have sufficient time to make a real examination of every working place.

12. During the past year mining machines appeared to cause explosions at practically any time of the day, but locomotives caused explosions between 8:00 and 9:00 a.m. and at the noon period (11:00 a.m. to 1:00 p.m.).

13. Explosions from explosives occurred between 3:00 and 6:00 p.m. or at shot-firing periods, and at the end of the day shift and the beginning of the night shift.

14. At least 23 of the 34 explosions were caused by supposedly experienced men holding responsible underground positions: - superintendent, foreman, fire boss, shot firer, machineman, etc.

15. There was no month during the year 1929-30 in which no explosion occurred, and in only two months, May and November, did only one explosion occur.

16. Causes of ignitions from July 1, 1929, to June 30, 1930, were: Electricity, 52.5 per cent; open lights or smoking, 23.5 per cent; explosives, 18.0 per cent; and unknown causes, 6.0 per cent.

17. One hundred and ninety-nine deaths resulted from explosions in 1929-30. An increase of 61 deaths or 77.8 per cent was recorded for explosions started by electrical equipment; 65 or 42 per cent of the deaths from electrical ignitions occurred in mines in which auxiliary or booster fans were installed underground and there is good reason for the belief that the failure to secure adequate ventilation with this method allowed gas to accumulate, forming an explosive mixture that was ignited electrically.

18. Open lights caused 21 fatalities, or 10.5 per cent of the deaths resulting from explosions. Of this number, 16 deaths or 76.2 per cent, were in an explosion in which a booster fan was directly involved.

19. Of the 24 deaths resulting from explosions caused by explosives, 23 were in mines in which ventilation was controlled in part by underground fans.

20. Ninety-nine, or almost one half of the 199 explosion fatalities resulted from defective ventilation in which underground fans were directly involved.

21. Twenty-three and five-tenths per cent of the mine explosions were in open-light mines and 73.5 per cent were in closed-light mines.

22. At least 27 men saved their lives by erecting barricades after mine explosions.

Mine Fires

23. During the year ended June 30, 1930, there were reported 24 mine fires; 19 in coal mines, 4 in metal mines, and 1 in a railroad tunnel. This shows an increase over the previous 12-month period, in which 13 coal-mine fires and two metal-mine fires were reported.

24. Kentucky had 4 mine fires, Ohio 3, and California, Indiana, Michigan, Pennsylvania, and West Virginia, had 2 fires each. There were 2 deaths from mine fires in Ohio, 2 fatalities in Kentucky, and 1 death in Michigan.

25. Nine fires were of electrical origin. An electric heater caused 1 fire, trolley wire was responsible for 6 fires, and cables caused 2 fires.

26. The value of barricades was shown during a recent mine fire, in which 89 men, comprising three separate groups, were probably saved by erecting barricades.

27. Open lights or smoking caused six mine fires. Ignition of gasoline underground caused 1 fire, smoking caused 2 fires, and 2 fires resulted from ignition of gas by open lights.

28. Three fires caused by black blasting powder were called to the attention of the safety division during the fiscal year 1929-30.

29. Seven fires were in open-light mines and eight in closed-light mines.

MISCELLANEOUS MINE ACCIDENTS

30. Electric wiring and apparatus should be adequately guarded and should be so enclosed that no arcs or sparks may be given off externally and thereby ignite fumes wherever gasoline or other volatile combustible liquids are used or stored.

31. Even in metal mines, nonpermissible electric flash lights should not be used while handling explosives. It appears likely that an explosion of dynamite in which five men were killed were caused by the premature igniting of a detonator that came in contact with the case of a nonpermissible flash light.

32. Deaths from contact with electricity in mines are increasing in number and frequency, and there is no question that bare wires in mines less than 6½ or 7 feet above the rail should be guarded throughout essentially every foot of their entire length. In a recent study of fatalities by electrical contacts in the coal mines of one State during the past five and one-half years, it was found that there had been 71 fatalities from electrical contacts in the five and one-half year period, 63 being from 250 volts d.c., 5 from 220 volts a.c., one from 2,300 volts a.c., one from 3,300 volts a.c., and in one instance voltage was not given. The trolley wire with voltage 250 or less was responsible for 55 of the 71 fatalities. Certainly the unguarded electric wire is a menace to the safety of underground workers; the so-called low-voltage, 250-volt, d.-c. trolley wire is little short of barbarous when used in or around mines unguarded and placed less than 6½ or 7 feet above the rail.

33. Wherever explosives are transported by automobile truck, every precaution should be taken to prevent premature explosions by electric sparks or arcs or by flames.

34. After blasting in rock tunnels or other places where more than one shot is fired at a time, extra care should be taken to prevent striking an undiscovered misfired shot or loose explosives in the coal or muck pile, and this is particularly true where delay-action detonators have been used for some of the shots.

35. Explosives, other than those of a type known to give off the minimum amount of poisonous gases, are dangerous to use in mines or quarries where there is probability of fumes being confined; therefore in all confined places the type of explosives employed should be given special care.

36. Every engine used to hoist men should be equipped with an overwinding and overspeeding device. Accidents of various kinds while handling men in cages, skips, or buckets in shafts or in trips on inclines are far too numerous.

37. Three fall-of-rock accidents, resulting in eight fatalities, were caused by loosening of overhanging rock by blasting. Four accidents, in which 15 lives were lost, were caused by falls of large quantities of rock, or cave-ins, in most cases due to poor mining methods or practices.

38. Explosions in a powdered coal plant, a bronze-dust plant, and in a zinc-dust plant were in large part the results of fires being fanned into hot flames by blower fans. It is necessary to take precautions to prevent the forming of fires in such plants, and in general it appears advisable that all blower fans should be stopped as soon as a fire is discovered.

39. At least 160 of the 199 fatalities from explosions were due to mechanized devices and equipment used in mining operations of various kinds. At least 9 of the 24 fires and 2 of the 5 fatalities from fires were due to mechanical equipment; and at least 9 of the 29 miscellaneous accidents, together with 18 of the 72 fatalities were also due to mechanization.

40. First-aid training is of benefit in practically every person's work and in many accidents the knowledge of how to stop bleeding may save a person's life. Every person working in or around any kind of mine or mining plant should be well trained in efficient up-to-date methods of giving first aid to the injured.